**REPORT:**

# Are recreational boats moving aquatic invasive species between Alaskan marine waters and Yukon freshwaters through bilge water?

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December 1, 2020

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**Marine aquatic invaders in the Yukon: What is the problem?**

In the Yukon, we have so far been very fortunate to have few aquatic invasive species (AIS) invasions.[1] However, residents and tourists frequently transport watercraft between Yukon freshwater systems and the marine waters of Haines and Skagway in Alaska. There is concern that residual water in the bilge and live wells of boats may transport invasive species from these marine areas into freshwater bodies in the Yukon. This report is an investigation into the risks that this pathway of AIS spread poses to Yukon waterways.

**How do aquatic invasive species move to new habitats?**

AIS are becoming an increasing problem around the world. Historically, the spread of aquatic species to new environments has been limited by natural barriers, such as drainage divides, mountains, and oceans.[2] Because of the current scale of human transport systems, there is unprecedented and rapid connectivity between previously well-separated and distinct bodies of water. AIS can be spread deliberately, through the stocking of lakes or through aquaculture practices.[3] However, most human pathways of AIS spread do not occur with the intention of establishing a new population of an invasive species. AIS can be present in the bilge and ballast water of ships and recreational watercraft and be released after travel to new locations; they be spread when aquaria pets are released in novel locations; they can be moved in garden or aquaculture waste; they can be transported as bait; and they can be introduced to new areas when attached to equipment such as boats and fishing gear.[4, 5] Important groups of aquatic invaders include molluscs, fishes, decapods, aquatic plants, and diseases, as well as barnacles, tunicates, and bryozoans.[6]

Much of the research around spreading AIS in North America has come from the Great Lakes region. Transfer of ballast water between foreign ports and the Great Lakes has led to the release and establishment of AIS, and even domestic shipping operations have spread these invaders between bodies of freshwater within North America.[7] These pathways of spread have been successful in part because of the broad range of environment tolerances of the species that have moved and then been able to establish, and in part because high propagule pressure contributes to successful establishment of sustained populations.[8, 9] High propagule pressure refers to the idea that a higher quantity and frequency of released AIS individuals in life stages that are able to establish a population means that there is a higher chance of that species surviving and establishing a population in a new environment.[10]

**Risks of bilge water transport**

A case study by Montz and Hirsch looked at the number of free-swimming zebra mussel larvae in the residual water of boats that had been in lakes with established populations of zebra mussel.[11] They found few surviving larvae in live wells and bilges, which they attributed to several factors. First, higher densities of mussel larvae were found to reside further below the surface, meaning that boats travelling on the lake would be more likely to collect surface-level water and not water that contained high numbers of larvae. Second, small water volumes, such as those in the bilge, often have low concentrations of oxygen and high levels of fuel or oil contamination, both of which might reduce larvae survival.

In contrast to these findings, a study by Fletcher et al. found that bilge water transport may pose a risk of spreading larvae and fragments from AIS.[12] They found that larvae from multiple non-indigenous species were able to pass through bilge systems undamaged, though increased time spent in the bilge decreased likelihood of survival and subsequent success after discharge. Johnson et al. found aquatic species larvae in all residual water carried by boats but found significantly fewer larvae in bilge systems than in live wells, which showed the highest abundances of larvae.[13] These results indicate that AIS may be spread through bilge water, but there is a higher likelihood that they will be transported to and establish populations in new areas when large volumes of water are frequently moved from areas with well-established populations of AIS.[14] On the Pacific coast, larval and juvenile forms of AIS, such as the invasive European Green Crab, could possibly be transported in bilge water. However, the European Green Crab has not yet been detected in Alaskan waters and has not been shown to survive and establish in freshwater environments.[15]

**Salinity: A barrier to aquatic invasive species spread and establishment**

Organisms generally have relatively narrow ranges of salinity tolerance, though some introduced species have broader ranges of tolerance to salinity. Species with wide tolerance are better suited to establish in a new environment if the salinity conditions are within their tolerance range.[16, 17, 18] However, many species that have been able to establish themselves in areas such as the Great Lakes have been those that tolerate a wide range of salinities, as they are able to survive marine transport conditions and are often able to survive when discharged in brackish environments.[19, 20, 21] For example, many Great Lakes invasive species originated in the Ponto-Caspian Region, which encompasses the Black Sea, Sea of Azov and Caspian Sea.[22, 23, 24] This may be because these species descended from freshwater species in the region, and their life histories enable them to make the transfer to freshwater environments when spread to environmentally variable habitats present in shipping ports.[25, 26]

In general however, we expect the risk of marine species moving into freshwater systems to be quite low, due to environmental mismatch and the osmotic shock that means that marine species are unlikely to survive in freshwater or vice versa.[27] Because of the salinity barrier, most AIS management is focused on the risk of transfer between bodies of freshwater, though there are several cases where AIS are being watched in marine and freshwater environments. For example, the Alaska Department of Fish and Game is learning about invasive northern pike moving from freshwater systems, through marine waters to access new and previously uninhabited freshwater habitats.[28] Other species of concern along the Pacific coast are Chinese mitten crabs, European Green Crabs, and the New Zealand Mudsnail, which all have life stages that could be spread in residual water on board recreational boats.[29] The brackish and freshwater inhabiting Chinese Mitten Crab has been introduced to California and could possibly spread up the BC coast,[30] but it has not yet been found in Alaska.[31, 32] European Green Crabs are invasive along the Pacific coast but not known to survive freshwater.[33, 34] The New Zealand Mudsnail is somewhat tolerant of salinity, and could possibly survive in ground water springs in harbours and some estuarine habitats,[35, 36] though it has also not yet been detected in Alaskan waters.

**Conclusions: What are the risks of transferring aquatic invasive species between Alaska and Yukon, and how do we minimize them?**

Marine AIS face a significant salinity barrier to establishment in freshwater systems. Foreign freshwater AIS that arrive in Alaska via shipping and ballast water are unlikely to survive very long in a marine environment (though there is a risk that they could survive in a brackish estuarine environment), and thus it is unlikely that they would be picked up in the small amount of residual water on board recreational boats that are then transported between the Pacific coast of Alaska and inland Yukon waters. It is also unlikely that AIS adapted to saline marine environments would be able to survive and establish themselves in freshwater systems. However, the risk of marine invaders establishing in Yukon waterways should not be dismissed, as this has occurred in areas such as the Great Lakes.[37] Presently, few marine invaders are established along the coast of Alaska, even though it has high shipping traffic and release of ballast water[38] which can contain AIS that exhibit tolerances to a broad range of salinities. Additionally, transport of recreational boats on the coastal ferry system may provide a pathway of spread for freshwater AIS to Alaska and overland to Yukon waters. Because more AIS may yet be introduced to Alaskan freshwater and marine systems, the best practice to minimize possible AIS transport to and establishment in Yukon waters is to continue to always Clean, Drain, and Dry all boats, aquatic equipment, trailers, and gear between uses. Before transporting watercraft or equipment, available marine wash stations should be used to clean boats and equipment and drain plugs should be pulled to allow complete drainage of tanks holding water.

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